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7-24-2007

Energy Cost Comparisons of Centre Pivot Systems in the Northern Texas High Plains

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Introduction

Irrigation is important for crop production in the Texas High Plains (THP), which is one of the most intensively cropped areas in the United States. Irrigated production is a vital component of the regional economy with corn, cotton, sorghum and wheat as the major crops. Irrigation water supplies in this region are mainly from the Ogallala aquifer with withdrawals increasing approximately five fold in fifty years in the THP (USGS, 2004). Despite its large size, the Ogallala recharges very slowly and its available water volume has been steadily declining over the past two to three decades. Water level declines have resulted in increased costs for ground-water withdrawals due to increased pumping lift and decreased well yields. Adoption of more technically efficient irrigation systems may overcome this problem to facilitate production by maintaining consumption with reduced application.

Choice of technology is a long-term decision. Methods of irrigation that require more water to irrigate an acre of land often play a significant role in depletion of an exhaustible groundwater aquifer. A common policy for conserving water is to encourage the adoption of more efficient irrigation technologies. For irrigators, high efficiency systems are potentially an effective way of counteracting ground water depletion. It would benefit them primarily through increased crop yields and reduced costs. Many studies have provided evidence that modern irrigation technologies such as drip and sprinkler can yield higher expected profits than traditional technologies (McKenry, 1996). These systems are a key to increase water use efficiency and reduce the use of scarce inputs (Cason and Uhlaner, 1991) while maintaining current levels of production.

Many factors like water availability, application efficiency, energy cost, crop mix and commodity prices tend to have an influence on the adoption rates of modern irrigation technologies. The energy cost for operating an irrigation pumping plant is a major concern to most farmers. Most of them look closely at their pumping efficiencies to consider converting from medium and high pressures systems to low-pressure systems as a measure to find ways to reduce energy costs. A study was done to compare energy costs of high, medium, and low-pressure sprinkler systems in the North Texas High Plains and to estimate the amount of savings in dollar terms by adopting the change.

Background

The irrigated agriculture in the U.S critically depends on ground water supplies. Of fourteen million acres irrigated in areas where ground water aquifers are declining, four million are located in Texas (National Research Council, 1996). Moreover, majority of this acreage in Texas is located in the High Plains region. Irrigation allows producers to grow high-volume crops that otherwise would not be possible due to low rainfall. Surface irrigation is the most common method of applying irrigation water in arid areas. Traditional irrigation technologies apply large quantities of water in a short period. Gravity spreads the water, which often results in non-uniform application.

The modern methods of applying irrigation are subsurface, sprinkler and drip irrigation (Troeh et al., 1999, Schwab and Frevert, 1985). Sprinkler irrigation systems are high pressure and high flow systems where sprinklers and laterals pump and distribute the water in small quantities continuously over longer periods uniformly throughout the field. These systems are steadily replacing traditional irrigation methods like furrow and other types of sprinklers, and have an application efficiency of 80 to 85 percent. The Irrigation Survey 2000 from Texas Water Development Board reports that there is a steady increase in the number of acres under sprinkler systems with 1.8 million acres in the northern Texas High Plains in year 2000. The figure 1 below shows the trend in adoption of sprinkler systems through 1989-00 in the high plains region.

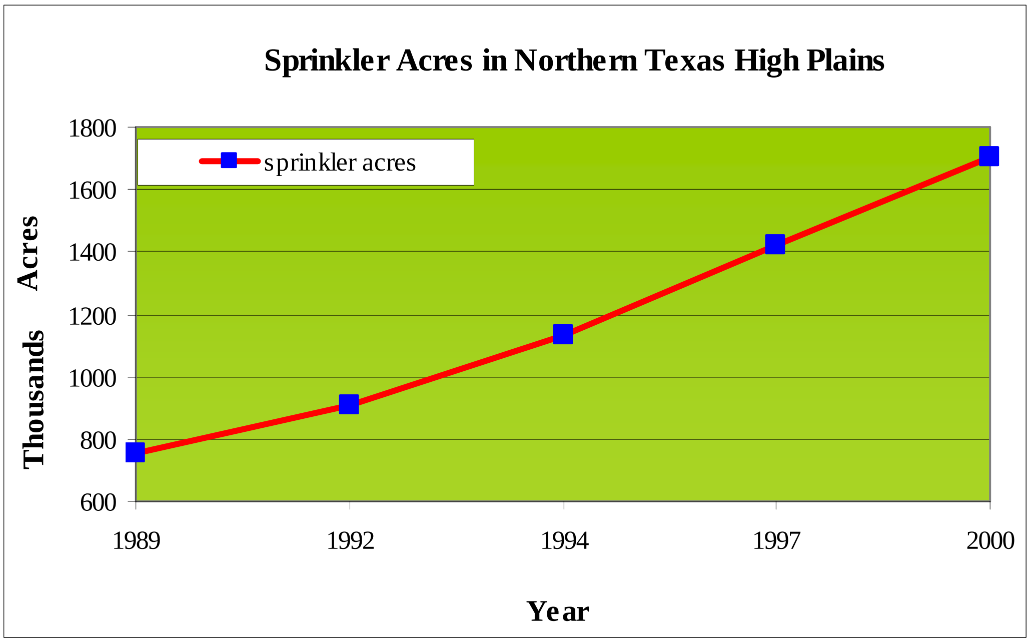

Figure 1: Sprinkler acres in the northern Texas High Plains
Source: Irrigation Survey, TWDB 2001

Studies indicate that a nationwide change in acreage with modern irrigation technologies was not gradual, but occurred mostly during brief periods associated with extreme events like drought and high-energy prices. Adoption of technically efficient irrigation systems can mitigate the effects of drought by allowing the irrigators to maintain water consumption with reduced applications. Irrigators can respond to drought in a variety of ways, in the short term they can reduce water applications, fallow acreage or change crops, whereas in the long term, they can adopt efficient irrigation systems. These systems increase the amount of water that can reach the crop in periods of low rainfall and transmit a higher proportion of water applied to the root zone of the crop. This encourages more efficient water use by crops, meaning a farmer can reduce the rate of application while still meeting the consumptive demand for the crop.

Converting to systems with higher application efficiency may affect water use, crop yield, and irrigation costs. One of the primary advantages of technically efficient irrigation system is the irrigation cost reduction associated with reducing the volume of the water delivered and energy used to pump the water. Improvements in irrigation efficiency frequently correspond to moderate yield improvements (Zilberman, 1995) and can reduce production costs. Efficient systems require fewer pumping hours for a given amount of irrigation, resulting in reduced operating expenses per hour (Williams et al, 1997). Both yield increase, cost reduction can improve farm profits, and this is one of the factor that drove the rapid conversion from flood to center-pivot systems in the High Plains in the 90's (Peterson and Bernardo, 2003).

High irrigation water demands in combination with escalating energy prices and declining well capacities played a key role in growers' decisions. Natural gas is the main source of energy to pump groundwater in the Texas High Plains. The gas prices have shown an average steady increase for the past ten years. Moreover, energy is an immediate cost; the irrigator is often more interested in reducing readily apparent energy costs than solving problems, such as poor water management or high seepage losses. Many irrigation-pumping systems installed during the low energy prices were not even very efficient. To maintain efficient pumping, modifications to the pump are generally necessary to reduce pressure head and increase flow. Reducing the pressure requirements of an irrigation system cuts down the amount of energy it consumes. Some irrigators consider converting from medium to high-pressure sprinkler back to surface irrigation systems to reduce or eliminate energy costs. Most irrigators who use center-pivot or linear move sprinkles are converting to low-pressure application devices on their systems to reduce energy costs. The figure 2 below shows the trend of natural gas prices through 1997-06 in the state of Texas.

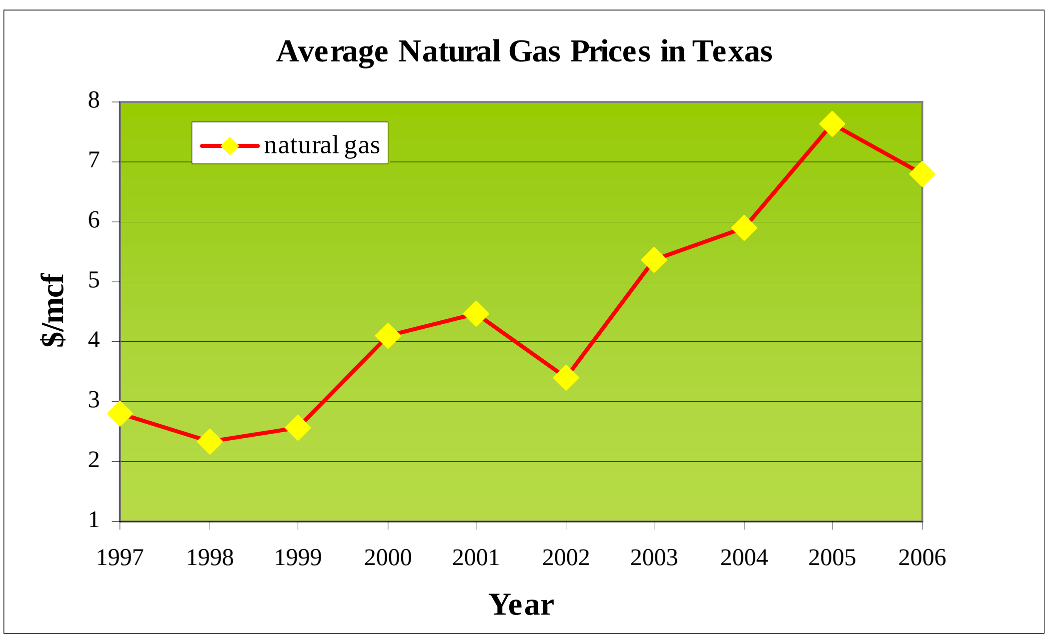

Figure 2: Average annual natural gas prices in the state of Texas
Source: Energy Information Administration

The center-pivots are the leading method of crop irrigation in many agricultural regions across the United States. About 75 percent of the acres in the THP utilize center pivot systems. Of these, 45 percent are low-pressure, 45 percent are medium pressure and 10 percent are high-pressure systems (Census of Agriculture, USDA 2002). Energy efficiency is an additional benefit of newer center-pivot systems. The first centre-pivots had high-pressure sprinklers, but as energy costs increased low-pressure sprinklers were developed to reduce operating costs. Most new center pivot installations use low-pressure sprinkler heads in which the flow pumped to the system remains the same, but the pressure head is reduced. This saves energy.

With declining water resources and escalating energy costs, total irrigated area in the Great Plains will likely decrease; however, the remaining irrigated land will likely see greater adoption of efficient irrigation technology and techniques, including deficit irrigation, irrigated dry land rotations (Stewart et al., 1983; Unger and Wiese, 1979), and careful irrigation scheduling (Howell et al., 1998a). The continued reduction of irrigated area and adoption of efficient water technology will further moderate the rate of energy use and contribute to sustainability of this irrigated agriculture driven economy.

Theoretical research has identified three broad classes of factors affecting irrigation technology adoption: economic variables, environmental characteristics and institutional variables. This paper investigates mostly issues associated with the economics of irrigation technologies. We estimate the energy costs using natural gas for the centre-pivot systems under high, medium and low-pressure sprinkler heads.

Methodology

Costs associated with irrigation systems provide a base for number of management decisions. Several factors like the crop under irrigation, the amount of irrigation water applied and the price received for higher yield may affect the point at which it becomes economically justified. The analyses of adoption and diffusion of irrigation technology choices should also incorporate physical and irrigation specific features of the new technology, such as irrigation efficiency, capital and equipment costs, as well as land quality and water quality. Economic considerations suggest that the propensity to adopt irrigation technology in a field depends on expected savings in the pumping costs from such adoption.

Every gallon of water pumped consumes energy. For a given system, an increase in water use results in a proportionate increase in energy consumption. The choice to convert from high pressure to low pressure systems depends mostly on economic and technical factors. A change from high and medium pressure to low-pressure systems reduces the pumping costs. The annual energy required to pump irrigation water depends on both the quantity pumped and the total head. System pressure required changes from one type of system to another. In this situation, both lift and system pressures are varied to determine the energy costs associated with the change.

The natural gas and electricity are the two major sources of energy used for pumping irrigation water in the Texas High Plains region. The fuel units per ac-ft per feet for natural gas used for estimating energy costs are from The Nebraska Pumping Plant Performance Criteria (NPC). Costs of centre pivots systems under high-pressure (80 psi), medium-pressure (45 psi) and low- pressure (25 psi) at five different well depths of 250, 300, 350, 400 and 450 feet were determined on a 120-acre cropland. Since corn dominated the irrigated acreage in the northern Texas High Plains, average irrigation levels applied for corn crop were used. As a final step savings estimated in dollars per acre by converting from high and medium-pressure systems to low-pressure are compared.

Results

These results will guide an irrigator through a basic assessment of his irrigation system. The costs increased with the increase in natural gas prices as well as with increasing pumping lift. Table 1 shows the seasonal costs of low, medium and high-pressure systems calculated at various depths and at different natural gas prices. The energy costs increased as the gas prices and the pumping lift increased. The energy costs ranged from $ 75/acre for low-pressure systems at 250 feet pumping lift to $337/acre under high-pressure systems at 450 feet pumping lift. These costs would also give the irrigator some idea whether his system is performing at a proper level.

Table 1: Energy Costs of Systems under Low, Medium and High-Pressures in $/acre

250 Feet	**Low Pressure**	**Medium Pressure**	**High Pressure**
$6	75	94	116
$8	101	125	154
$10	126	157	193
$12	151	188	231
300 Feet			
$6	88	107	129
$8	117	143	172
$10	146	179	215
$12	176	215	233
350 Feet			
$6	100	121	142
$8	133	161	189
$10	167	202	237
$12	200	241	284
400 Feet			
$6	112	134	155
$8	150	179	207
$10	187	223	259
$12	225	268	311
450 Feet			
$6	125	147	169
$8	166	196	225
$10	208	245	281
$12	249	294	337

The figure 3 below shows the graphical representation of the energy costs per acre at different natural gas prices at 350 feet pumping lift. At lower gas prices, the energy costs of the high-pressure system were $140 per acre and $100 per acre for the low-pressure system. As the natural gas prices increased the energy cost were $284 and $200 per acre for high and low-pressure systems respectively.

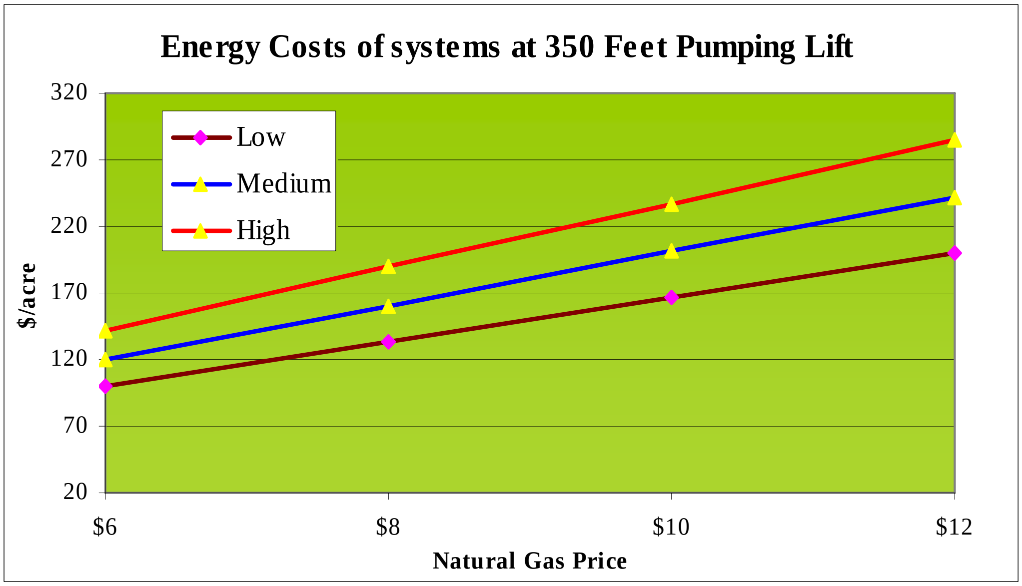

Figure 3: Energy costs of system at three different pressures at 200 feet pumping lift

The amount of savings in energy costs in $/acre per season are shown in Tables 2 and 3. The estimated results showed that a farmer could save around $19 to $45 per acre per season by converting from medium-pressure to low-pressure systems whereas, he/she could save about $40 to $88 per acre per season by converting from high-pressure to low-pressure system under low and high gas prices respectively.

Table 2: Savings in $/acre per season by converting from Medium to Low Pressure

	Natural Gas Prices			
Pump lift (Feet)	**$6**	**$8**	**$10**	**$12**
250	19	25	31	37
300	20	26	33	39
350	21	27	35	41
400	22	29	36	43
450	23	30	38	45

Table 3: Savings in $/acre per season by converting from High to Low Pressure

	Natural Gas Prices			
Pump lift (Feet)	**$6**	**$8**	**$10**	**$12**
250	40	53	67	80
300	41	55	68	57
350	42	56	70	84
400	43	57	72	86
450	44	59	73	88

Conclusion:

Pumping less water (possibly at lower pressures) through improved irrigation procedures will aid in decreasing the continuing energy needs. A change in pressure may reduce energy needs of the farmer for pumping irrigation water. The energy costs estimated in the study ranged from $75 to $337 per acre per season whereas, savings ranged from $19 to $45 per acre by converting from medium to low pressure and from $40 to $88 per acre by converting from high pressure to low pressure systems. As energy costs continue to increase, efficient irrigation systems mean more money in your pocket.

References

Cason, T.N., and R .T. Uhlaner. " Agricultural Production's Impact on Water and Energy Demand: A Choice Modeling Approach." Resource and Energy 13(December 1991)

Energy Information Administration (EIA). Accessed on April 30 2007. Available at: http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_STX_m.htm

Howell, T. A., T. H. Marek, L. L. New, and D. A. Dusek. 1998a. Weather network defends Texas water tables. *Irrig. Business and Tech.* VI (6): 16-20.

McKenry, M. "The Transition to Hi-Tech Agriculture." Paper Presented at Conference on the Future of Central Valley Agriculture, Parlier, CA, June 21, 1996

Peterson, J.M., and D.J. Bernardo. "High Plains Regional Aquifer Study Revisited: A 20 Year Retrospective for Western Kansas." Great Plains Research 13(2003): 179-197

Schwab, G. O and R. K. Frevert. 1985. Elementary and Water Engineering. John Wiley and Sons.

Shah. A. F., D. Zilberman, and U. Chakravorthy. May 1995 " Technology Adoption In The Presence Of An Exhaustible Resource: The Case Of Groundwater Extraction".

Stewart, B. A., J. T. Musick, and D. A. Dusek. 1983. Yield and water use efficiency of grain sorghum in a limited irrigation-dryland farming system. *Agron. J.* 75(4): 629-634.

Texas Water Development Board Report 347 August 2001 Available at: http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R347

Troeh, F. R., J. A. Hobbs, and R. L. Donahue. 1999. Soil and Water Conservation. Prentice Hall

Unger, P. W. and A. F. Wiese. 1979. Managing irrigated winter wheat residue for water storage and subsequent dryland grain sorghum production. *Soil Sci. Soc. Am. J.* 43(3): 582-588.

U.S. Department of Agriculture, 2002, National agricultural statistics service, 2002 Census of Agriculture. Available at http://www.nass.usda.gov/census/

U.S. Geological Survey, 2004, Water Use in the United States: U.S. Geological Survey data, Available at http://water.usgs.gov/watuse/.

Williams, J.R., R.V. Llewelyn, M.S. Reed, F.R. Lamm, and D.R. DeLano. "Economic Analysis of Alternative Irrigation Systems for Continuous Corn and Grain Sorghum in Western Kansas." Report of Progress 766, Agricultural Experiment Station, Kansas State University, May 1997

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